

# Predation on Juvenile Chum Salmon *Oncorhynchus keta* by Fishes and Birds in Rivers and Coastal Oceanic Waters of Japan

**Kazuya Nagasawa**

Nikko Branch, National Research Institute of Aquaculture

Fisheries Research Agency, Chugushi, Nikko

Tochigi 321-1221

JAPAN

Email: ornatus@fra.affrc.go.jp

**Hiroshi Kawamura**

Kumaishi Branch

Hokkaido Fish Hatchery

Ayukawa 189-43, Kumaishi

Hokkaido 043-0402

JAPAN

Email: kawamurah@fishexp.pref.hokkaido.jp

**Key Words:** predation, natural mortality, chum salmon, *Oncorhynchus keta*, piscivorous fish, fish-eating birds.

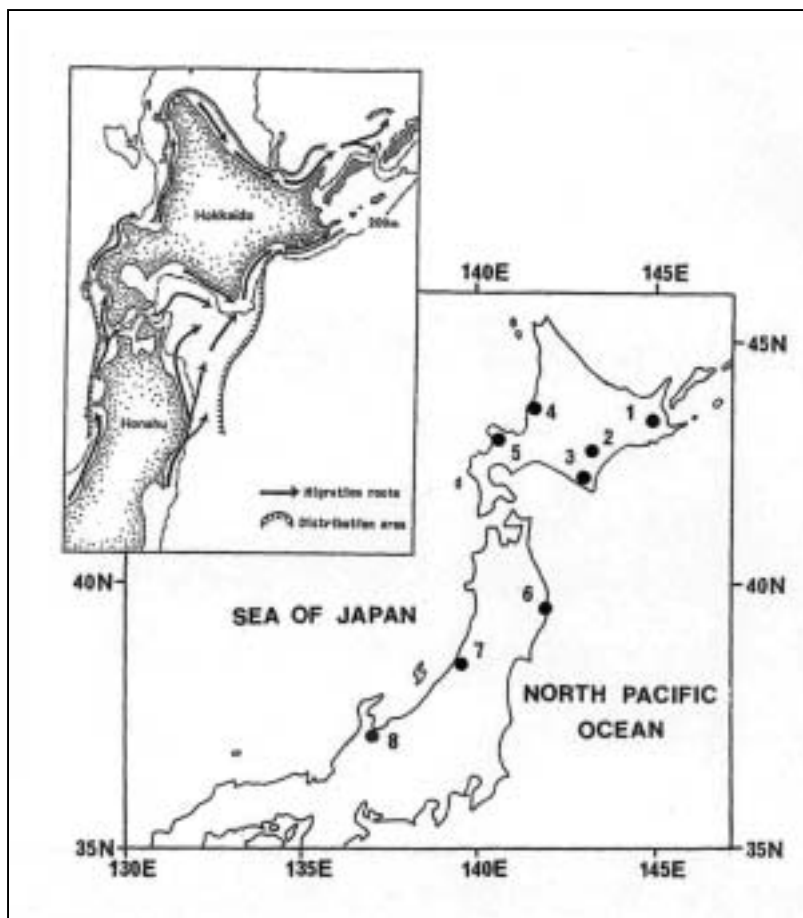
## Abstract

The present paper compiles information on predation by fishes and birds on juvenile chum salmon (*Oncorhynchus keta*) in rivers and coastal oceanic waters of Japan. In Japan, nearly 100% of chum salmon juveniles are reared at hatcheries and released into rivers. Various freshwater fishes, such as sculpins, gobiids and Japanese dace (*Tribolodon hakonensis*) are known to feed on released chum salmon juveniles. In this paper, detailed information is given about predation by fluvial sculpin (*Cottus nozawae*) in a river of southern Hokkaido. Evidence shows that sculpin preyed on chum salmon juveniles, but their impact on the population was low. Gulls and other birds aggregate at river-mouths during the season of chum salmon release and feed heavily on juveniles. A recent survey on the impact of avian predation on the chum salmon population in a river of western Hokkaido has shown that over 10% of released juveniles were consumed by gulls (black-tailed gulls *Larus crassirostris* and slaty-backed gulls *L. schistisagus*) for nine days after release, indicating that the gulls are significant predators. Gulls are the most abundant seabirds in coastal waters of Hokkaido, and their predation may be present in coastal oceanic waters as well. Night releases are highly recommended to reduce loss of chum salmon by avian predation in river-mouth regions.

Natural mortality is one of the most important factors controlling fish populations, and predation is a major source of natural mortality for juvenile Pacific salmon (Ruggerone, 1986; Wood, 1987; Rieman *et al.*, 1991; Ruggerone and Rogers, 1992; Beamish *et al.*, 1992; Collis *et*

*al.*, 2001). In Japan, nearly 100% of juvenile chum salmon *Oncorhynchus keta* are reared at hatcheries and currently about two billion fish are released into rivers every spring (Kaeriyama, 2000). These juveniles travel to the sea and migrate along the coast of northern Japan to the southern Sea of Okhotsk (Fig. 1). Life history information on distribution, migration and feeding patterns is available, but little is known about the species' natural mortality, especially predation.

Nagasawa (1998) regarded the following nine fish species and two seabirds as major predators of juvenile chum salmon in coastal oceanic waters of Japan: Japanese dace *Tribolodon hakonensis*, Far Eastern dace *T. brandti*, white-spotted charr *Salvelinus leucomaenis*, Japanese halibut *Paralichthys olivaceus*, Japanese sea perch *Lateolabrax japonicus*, spiny dogfish *Squalus acanthias*, arabesque greenling *Pleurogrammus azonus*, pink salmon *O. gorbuscha*, masu salmon *O. masou*, rhinoceros auklets *Cerorhinca monocerata* and black-tailed gulls *Larus crassirostris*. This paper reviews past literature and adds new research on fish and avian predation on chum salmon juveniles in Japanese rivers.



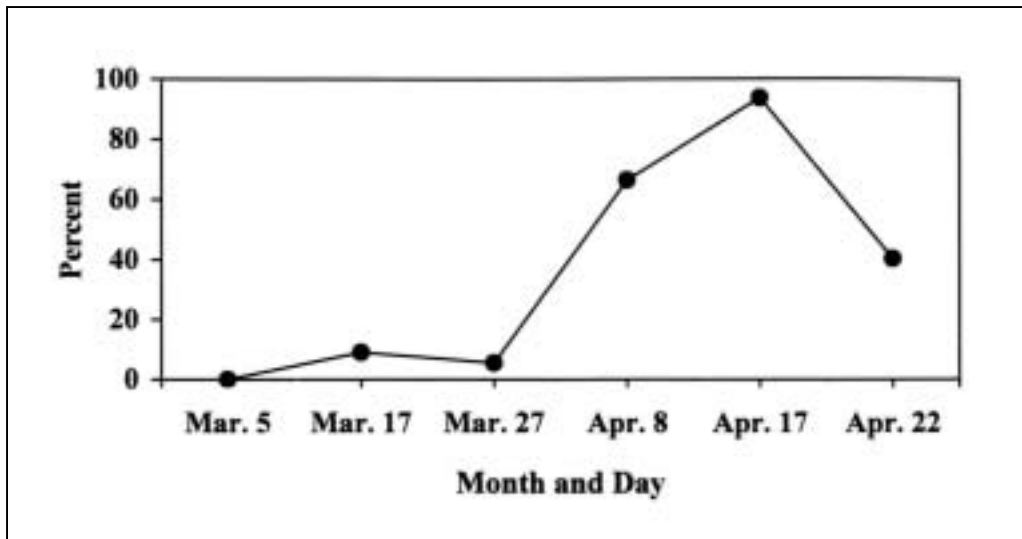
**Figure 1.** Migration route of juvenile chum salmon in coastal oceanic waters of northern Japan (modified from Irie, 1990), showing the locations of the Nishibetsu River (1), Memu River (2), Utabetsu River (3), Shokanbetsu River (4), Furuu River (5), Otsuchi River (6), Katsugi River (7), and Shou River (8).

### Predation in Rivers

There are several papers dealing with predation by white-spotted charr on chum salmon juveniles in Japanese rivers (Kubo, 1946; Hikita *et al.*, 1959; Takami and Nagasawa, 1996). In northern Japan, white-spotted charr are widely distributed and abundant in mountain streams and upper reaches of rivers. In eastern Hokkaido, Kunashiri and Iturup islands, Kubo (1946) found an average of 8.2 juveniles per stomach and regarded white-spotted charr as the most significant

predator. Many years later Takami and Nagasawa (1996) reported chum salmon in the stomachs of four (12.5%) out of 32 white-spotted charr in the Furuu River, western Hokkaido during the seaward migration period of both species (Fig. 1).

In Japan, masu salmon spend their first one to two years in rivers before migrating to the sea. During this time and during migration they prey heavily on juvenile chum salmon (Kubo, 1949; Hikita *et al.*, 1959). Tago (1994) reported the same in the Shou River of central Honshu (Fig. 1). Juvenile chum salmon are released from hatcheries during their natural migration period, late winter to early spring. In Tago's study the percentage of masu salmon ingesting chum salmon began to increase in mid- to late March, peaked in mid-April, and thereafter decreased (Fig. 2).



**Figure 2.** Seasonal changes in percent weight of chum salmon in the stomach contents of juvenile masu salmon from the Shou River, central Honshu, from early March to late April 1992 (original, raw data from Tago, 1994).

This trend corresponded with seasonal changes in abundance of sea-migrating chum salmon at sampling sites. In mid-April, a single chum salmon was usually preyed upon by one masu salmon.

Other salmonids known to feed on juvenile chum salmon in Japanese rivers include Dolly Varden *Salvelinus malma* (Kubo, 1946), Sakhalin huchen *Hucho perryi* (Kubo, 1946; Nakano, 1992), brook trout *Salvelinus fontinalis* and rainbow trout *Oncorhynchus mykiss* (Kubo, 1946; Hikita *et al.*, 1959). Of these species, Sakhalin huchen and Dolly Varden have such small populations in restricted rivers that the impact of their predation on chum salmon populations is minimal. Brook trout and rainbow trout populations are also low because they usually do not breed in northern Japan, suggesting a minimal impact. However, the latter two salmonids are known to reproduce abundantly and feed on chum salmon in some rivers of Hokkaido, such as the Nishibetsu River (Fig. 1 - Kubo, 1946; Hikita *et al.*, 1959). Japanese dace are also known predators, although insignificant in rivers (Inukai, 1949).

The most well studied predator of juvenile chum salmon in Japanese rivers is the fluvial sculpin *Cottus nozawae* (Hikita and Nagasawa, 1960; Kawamura, 1980, as *C. pollux*; Nagata, 1984; Nagata and Miyamoto, 1986). Fluvial sculpin mainly occur in the lower and middle reaches of rivers in Hokkaido and northern Honshu. They feed on a wide variety of organisms, such as aquatic insects, benthic animals, small fish and salmon eggs (Goto, 1989). Predation on chum salmon by fluvial sculpin has been studied in two rivers, the Memu River and Utabetsu River, Hokkaido (Fig. 1). Detailed information is given in the next section.

Another species of the freshwater sculpin, *C. hangiongensis*, has been reported to prey on chum salmon in the Otsuchi River, northern Honshu (Fig. 1 - Hiyama *et al.*, 1972a; 1972b). In April of 1964-65, juveniles were found in the stomachs of sculpin 13.2-35.7% of the time. At least 68 juveniles were found in the stomachs of 48 sculpin (1.4 salmon per sculpin).

The floating goby *Chaenogobius urotaenia* and Japanese trident goby *Tridentiger obscurus* are predators of chum salmon juveniles in Japan (Hiyama *et al.*, 1972a; 1972b; Amida and Okada, 1973). Information on predation by these gobies is very limited and there are only a few records from two rivers. In the Otsuchi River, northern Honshu, 29 (3.5%) out of 823 floating gobies and 2 (6.5%) out of 31 trident gobies collected in April had 35 (mean 1.2) and 3 (1.5) chum salmon in the stomachs, respectively (Hiyama *et al.*, 1972b). Amida and Okada (1973) reported that floating gobies actively fed on chum salmon at night in the Katsugi River, central Honshu (Fig. 1). In late April, over 40% of the gobies sampled were found to have ingested juveniles.

No scientific information is available on avian predation on juvenile chum salmon in Japanese rivers, except the river-mouth regions. However, Sakurai (1984) states in his book that two species of kingfishers, crested kingfisher *Ceryle lugubris* and common kingfishers *Alcedo atthis*, prey on sea-migrating chum salmon juveniles in eastern Hokkaido. These birds are frequently observed along streams in northern Japan. Sakurai also mentions that black-backed wagtails *Motacilla alba* and brown-headed thrushes *Turdus chrysalaus* feed on juveniles. Since brown dippers *Cinclus pallasii* are known to eat juvenile rainbow trout stocked into rivers (Hiyama *et al.*, 1960) and occur widely in Japan, including the northern region, where chum salmon propagation has been extensively conducted, predation by this bird species on chum salmon is very likely.

#### Case Studies on Predation by Fluvial Sculpin

Various aspects of fluvial sculpin biology (Kawamura, 1979, as *C. pollux*) and predation (Nagata, 1984) were investigated in the Utabetsu River, southern Hokkaido. Kawamura (1980) and Nagata and Miyamoto (1986) conducted intense studies in 1978-80 and 1983-84, respectively. The Utabetsu River is mere 13 km long and drains directly into the North Pacific Ocean. Chum salmon are released in spring (from mid-April to early June, usually in late May) from a governmental hatchery located about 4 km upstream from the river mouth. The number of the fish released in 1978-80 and 1983-84 ranged between 1.45 and 3.27 million. The juveniles do not remain in this river long. About 50% enter the sea by the next day and the remainder by the following 12-24 days.

The abundance of fluvial sculpin varied by sampling location. The species was abundant (0.15 fish/m<sup>2</sup>) near the river mouth, but much less abundant (0.02-0.05 fish/m<sup>2</sup>) in the upper stream. The sculpin were collected using cast and dip nets in May 1983 and comprised six size groups. Fish of size group 2 were the most abundant (40.6%) at 6.70 cm in mean body length (BL), followed by those of size groups 3 and 4 (26.7%, 8.95 cm BL and 11.7%, 10.75 cm BL,

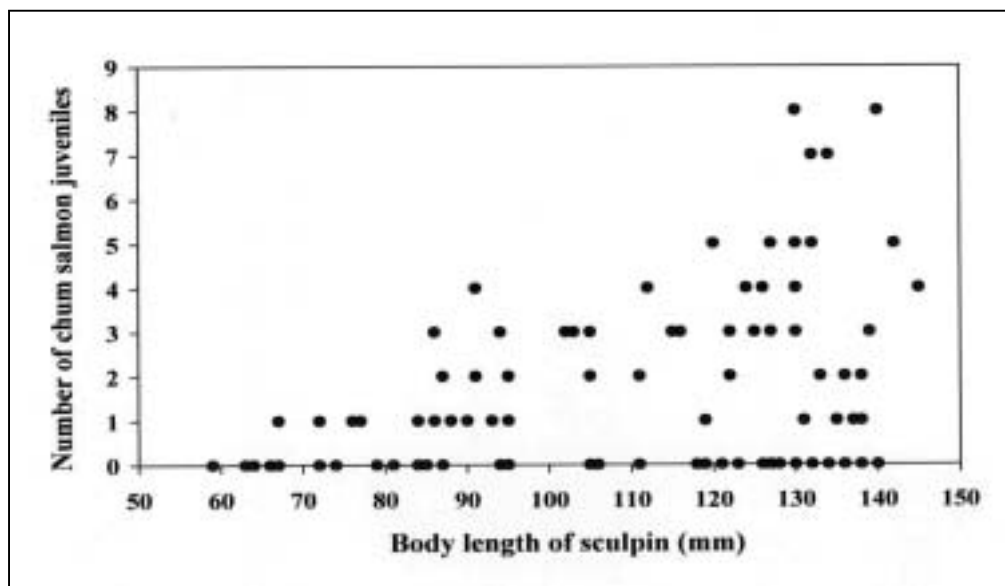
respectively). The largest sculpin collected measured 17.0 cm BL. These percentages were used to estimate the density of fluvial sculpin occurring in May 1983. A total of 1200 fish were estimated to occur throughout the two river regions (river-mouth region and upper-stream region to the hatchery). In addition, the satiation weight of prey ( $Y_w$ ) was determined by the body length ( $X$ ) of predator, as shown by the linear equation:

$$Y_w = 0.695 X - 4.381 \quad (1)$$

Feeding behavior of fluvial sculpin was also observed in a tank for seven days after the fish were satiated with chum salmon juveniles. The sculpin fed on few juveniles for the first three days, but fed actively for the remaining four days. The ratio of fish eaten in seven days to initial fish consumed for satiation decreased exponentially with an increase in sculpin body length. The relationship between ratio ( $Y$ ) and body length ( $X$ ) is shown by the formula:

$$Y = 111.902X^{-1.8201} \quad (2)$$

The percentage of fluvial sculpin ingesting chum salmon juveniles varied between years (27.9-72.2%), with larger sculpin ingesting a greater number (Fig. 3). As many as eight chum salmon were recovered from two large fish (13 and 14 cm BL), and an average of about 2.4 juveniles were found in a single stomach. The chum salmon found in stomachs were smaller than the released fish (e.g., 0.87 and 0.92 g for the 1983 and 1984 mean BW of ingested juveniles vs 0.92 and 1.29 g for released juveniles).



**Figure 3.** Relationship between number of chum salmon juveniles ingested and body length of fluvial sculpin (modified from Nagata and Miyamoto, 1986).

The total number of chum salmon consumed was calculated using equations 1 and 2, the mean BW of ingested fish and the number and mean BL of predator sculpin of each size group (with the exception of group 1). The result was estimated as 6638 fish eaten in 1983 and 6254 fish eaten in 1984 for eight days after each release. This was approximately 0.3% and 0.2% of the release number (2.51 and 3.27 million, respectively). Predation loss by the sculpin of size

group 1 was not included because they are too small (mean BL=3.25 cm) to prey on the chum salmon. The actual feeding rates of fluvial sculpin on chum salmon ranged between 27.9% and 72.2%, suggesting that the above predation rate was over-estimated. Therefore, the loss of juvenile chum salmon due to predation by fluvial sculpin appears to be minimal, making the sculpin insignificant predators in the Utabetu River.

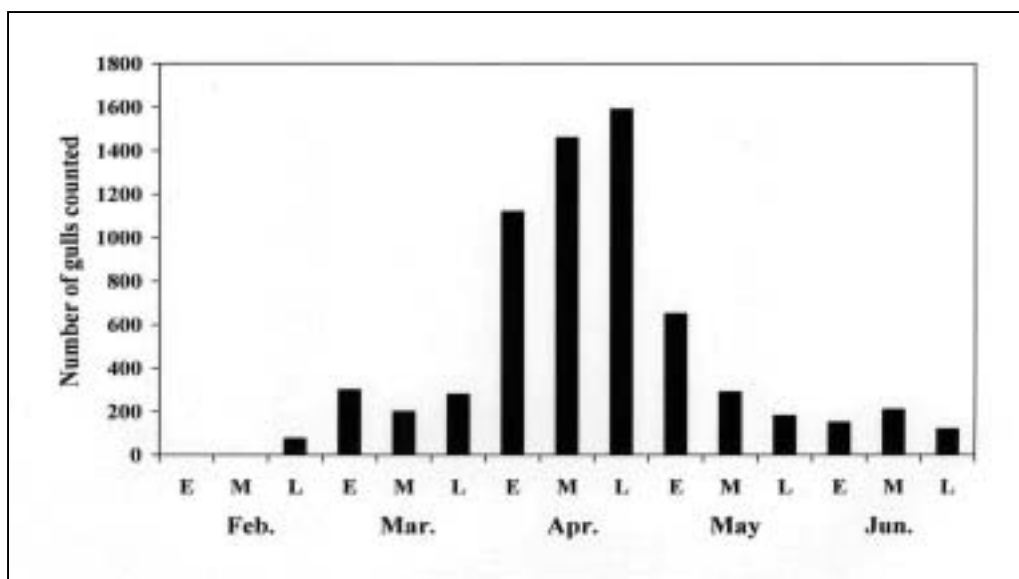
#### Predation in River-Mouth and Estuarine Areas

Nagasawa (1998) identified the Japanese dace, white-spotted charr and Japanese sea perch as predators of juvenile chum salmon in river-mouth and estuarine areas. Japanese dace are particularly abundant in these areas of northern Japan, where Kubo (1946) found them to feed before migrating to rivers. Their prey items were never identified, however. Further studies to determine their impact on chum salmon populations would be beneficial.

Recent studies have been conducted on predation by birds in these areas. In the river-mouth region of the Shokanbetsu River, western Hokkaido (Fig. 1). Kawamura *et al.* (2000) and Kawamura and Kudo (2001) observed the feeding behavior of several species of birds following a hatchery release in April 1999. The governmental hatchery is located about 7 km upstream from the mouth of the Shokanbetsu River (26 km total length). Approximately 13 million juvenile chum salmon were released in late April. Most of the fish were expected to reach the sea within 10 to 14 days post release (Kawamura, unpublished). Kawamura and the others used binoculars to count the number of gulls every 10 days from early February to late June in 1999 and observed the feeding behavior four times from late April to mid-May. They also counted the number of other birds from early April to late June. The highest count for each of the 10 days was used as a measure of the abundance of birds.

The two most frequently counted birds were black-tailed gulls *Larus crassirostris* and slaty-backed gulls *L. schistisagus*. They were followed by Japanese cormorants *Phalacrocorax filamentosus* (as *P. capillatus*, in Kawamura *et al.*, 2000), red-breasted mergansers *Mergus serrator* and harlequin ducks *Histrionicus histrionicus* (ibid). Two more species, glaucous gulls *L. hyperboreus* and little egrets *Egretta garzetta*, were reported by Kawamura and Kudo (2001). Of these, four species (slaty-backed gulls, black-tailed gulls, red-breasted mergansers, Japanese cormorants) were found to prey on chum salmon juveniles (Kawamura *et al.*, 2000; Kawamura and Kudo, 2001).

The number of gulls counted was low in February and March but peaked in late April at over 1500 birds (Fig. 4). This period of increase directly coincided with the chum salmon release. Subsequently, the number sharply decreased in early May and remained at low levels (100-300 gulls) from mid-May to late June. Red-breasted mergansers, normally winter visitors, were most abundant (about 90 individuals) in late April. Harlequin ducks steadily decreased to about 20 from April to June, probably because this species usually migrates further north. The number of Japanese cormorants increased from April to June with a peak at 70 in early June, not corresponding with the fish release.



**Figure 4.** Seasonal changes in number of gulls counted in the mouth region of the Shokanbetsu River, western Hokkaido, from early February to late June 1999 (modified from Kawamura *et al.*, 2000). Chum salmon were released in late April, when the number of gulls peaked.

Kawamura and Kudo (2001) used data from various feeding behaviors of gulls (e.g., feeding success) and values (e.g., satiation amount of prey per day) from other studies to estimate that gulls in a 250-m region from the river mouth consumed 1.44 million chum salmon during nine days after release. This figure is equivalent to 11.1% of the number of released juveniles (13 million), indicating that the gulls are significant predators in the Shokanbetsu River. The authors stated however that the estimate was low because the survey area was restricted and other fish-eating birds were present in the region. Detailed information on estimated loss of chum salmon due to gull predation will be published elsewhere.

One of the most important factors in estimating predation impact by gulls is that these birds feed heavily daily. Although no data are available on daily food consumption of wild Japanese gulls, Harris (1965) reported that a captive herring gull *Larus argentatus* (800 g BW) consumed up to 429 g of fish in 24 hours. They are known to consume 199-368 g of fish per day in captivity (Spaans, 1971). If these figures can be applied to Japanese gulls, 400 g of fish consumed by a single gull per day, for example, would be equivalent to 476 juvenile chum salmon (mean BW=0.84 g) released into the Shokanbetsu River in 1999.

#### Predation in Coastal Oceanic Waters

Nagasawa (1998) reported the following fish species as predators of chum salmon in Japanese coastal waters: Far Eastern dace, Japanese halibut, spiny dogfish, arabesque greenling, pink salmon and masu salmon. Kawamura *et al.* (2000) found chum salmon juveniles in the stomachs of arabesque greenling caught in a setnet on the west coast of Hokkaido. The juveniles were not digested, so the authors suspected the arabesque greenling consumed the fish after being caught in the net. Kawamura and Kudo (2001) also examined the stomach contents of 13 fish species caught in the Sea of Japan near the mouth of the Shokanbetsu River and found that

juvenile masu salmon and white-spotted charr had eaten small chum salmon. However, the authors did not regard these salmonids as significant predators because the seaward migration period of juvenile masu salmon is different from that of chum salmon juveniles and the abundance of white-spotted charr is very low in the survey area.

Rhinoceros auklets and black-tailed gulls are major predators in coastal oceanic waters of Japan (Nagasawa and Kaeriyama, 1995; Nagasawa, 1998). Rhinoceros auklets migrate to inshore waters off western Hokkaido from late April to late May (Kawamura *et al.*, 2000).

Takahashi *et al.* (2000) surveyed these birds in late May to July, after the coastal migration of chum salmon, on Teuri Island off western Hokkaido. They found unidentified salmonid juveniles (*Oncorhynchus* sp., annual percent occurrence of 1.1 to 3.4% in 1994-98) in the food given by adult rhinoceros auklets to their chicks. Sakurai (1984) also reported that the common tern *Sterna hirundo* feeds on chum salmon juveniles in coastal waters off eastern Hokkaido.

Along a 35-km shoreline of western Hokkaido from early April to late June in 1999, Kawamura (2001) identified 12 species of birds that peaked at approximately 3500 individuals in mid-April. Kawamura *et al.* (2000) also discovered juvenile chum salmon with beak marks on their lateral sides (Fig. 5) in late April near the Shokanbetsu River mouth, which is evidence of avian predation at sea. Based on the above information, seabirds are likely the major predators of juvenile chum salmon in the coastal sea. The most significant predators may be gulls, due to high abundance (Watanuki *et al.*, 1986; 1988) along the coast and river-mouths of western Hokkaido.



**Figure 5.** Photograph of juvenile chum salmon with beak marks, collected in the coastal Sea of Japan on April 27, 1999 (modified from Kawamura *et al.*, 2000).

#### Measures to Reduce Predation Loss, and Future Research

Watanuki *et al.* (1988) reported that 36,000-40,000 pairs of black-tailed gulls and 9,600-10,000 pairs of slaty-backed gulls bred each year on the coast of Hokkaido during the 1980's. The release of chum salmon into the Shokanbetsu River attracted large numbers of gulls to the river-mouth region (Fig. 4) where the gulls were found feeding on the fish. Kawamura and Kudo (2001) estimated that gulls consumed more than ten percent of the 1999 released fish for nine days after release. Releasing hatchery-reared fish at night may reduce the gulls' ability to see them and increase fish survival.

Much remains to be studied on fish and avian predation of juvenile chum salmon in Japan. Further research is needed to assess the impact of predation by Japanese dace that abundantly occur in river-mouth and estuarine regions of northern Japan and to study the feeding ecology of gulls in river-mouth regions and coastal oceanic waters. Research is also needed to clarify the anti-predator behavior of released juvenile chum salmon and to develop measures to reduce predation. In Honshu, along the Japan Sea coast, both chum and masu salmon are

frequently released into the same rivers. Since masu salmon are known to feed on chum salmon (Tago, 1994), investigations to estimate predation loss may show the need to identify different locations for release.

## Acknowledgments

We thank Yutaka Watanuki, Hokkaido University, Nariko Oka, Yamashina Institute for Ornithology, and Yu-ichi Osa, Hokkaido Institute of Environmental Sciences, for their help with the literature.

## Literature Cited

- Amida, K. and M. Okada.** 1973. Studies on mortality factors of chum salmon-I. Habits of the folk tongue goby as predator of chum salmon juveniles. *Aquaculture* 21:62-64 (in Japanese).
- Beamish, R. J., B. L. Thomson, and G. A. Mcfarlane.** 1992. Spiny dogfish predation on chinook and coho salmon and the potential effects on hatchery-produced salmon. *Trans. Am. Fish. Soc.* 121:444-455.
- Collis, K., D. D. Roby, D. P. Craig, B. A. Ryan, and R. D. Ledgerwood.** 2001. Colonial waterbird predation on juvenile salmonids tagged with passive integrated transponders in the Columbia River estuary: vulnerability of different salmonids species, stocks, and rearing types. *Trans. Am. Fish. Soc.* 130:385-396.
- Goto, A.** 1989. *Cottus nozawae*. In: H. Kawanabe, and N. Mizuno, (eds.), Freshwater Fishes of Japan, Yama-Kei Publ., Tokyo, p. 660-665 (in Japanese).
- Harris, M. P.** 1965. The food of some *Larus* gulls. *Ibis* 107:43-52.
- Hikita, T. and A. Nagasawa.** 1960. Biological observations of Memu stream, Tokachi River system. The damage of salmon eggs and fry by predaceous fishes. *Sci. Rep. Hokkaido Salmon Hatchery* 15:69-83 (in Japanese with English abstract).
- Hikita, T., S. Kameyama, A. Kobayashi, and Y. Sato.** 1959. Some biological observations on the rainbow trout, *Salmo gairdneri irideus*, in the Nishibetsu River, with special reference to the consumption of salmon eggs and fry by predaceous fishes. *Sci. Rep. Hokkaido Salmon Hatchery* 14:91-121 (in Japanese with English abstract).
- Hiyama, Y., Y. Nose, M. Shimizu, J. Matsubara, K. Onodera, Y. Kodama, and N. Suzuki.** 1960. Predation of rainbow trout fry traced by radio-isotope. *Bull. Japan. Soc. Sci. Fish.* 26:863-867 (in Japanese with English abstract).
- Hiyama, Y., Y. Nose, M. Shimizu, T. Ishihara, H. Abe, R. Sato, and T. Maiwa.** 1972a. Predation of chum salmon fry during the course of its seaward migration-I. Otsuchi River investigation 1961-1963. *Bull. Japan. Soc. Sci. Fish.* 38:211-221.
- Hiyama, Y., Y. Nose, M. Shimizu, T. Ishihara, H. Abe, R. Sato, T. Maiwa, and T. Kajihara.** 1972b. Predation of chum salmon fry during the course of its seaward migration-II. Otsuchi River investigation 1964 and 1965. *Bull. Japan. Soc. Sci. Fish.* 38:223-229.
- Inukai, T.** 1949. Feeding habit of Japanese dace in the Bibi River, Hokkaido. *Sci. Rep. Hokkaido Fish Hatchery* 4:57-61 (in Japanese).
- Irie, T.** 1990. Ecological studies on the migration of juvenile chum salmon, *Oncorhynchus keta*, during early ocean life. *Bull. Seikai Nat. Fish. Res. Inst.* 68:1-142 (in Japanese with English abstract).

- Kaeriyama, M.** 2000. Hatchery programmes and stock management of salmonids populations in Japan. In: B. R. Howell, E. Moksness, and T. Svendsen, (eds.), Stock Enhancement and Sea Ranching, Fishing News Books, Oxford, p. 153-167.
- Kawamura, H.** 1979. Distribution, movement and age constitution of the common freshwater sculpin (*Cottus pollux* Günther) in the salmon propagation river. *Sci. Rep. Hokkaido Fish Hatchery* 34:17-24 (in Japanese with English abstract).
- Kawamura, H.** 1980. Predation of chum salmon fry by common freshwater sculpins (*Cottus pollux* Günther) in the salmon propagation river. *Sci. Rep. Hokkaido Fish Hatchery* 35:53-62 (in Japanese with English abstract).
- Kawamura, H.** 2001. Coastal ecology and survival of chum salmon juveniles. *Uo to Mizu* 37:25-30 (in Japanese).
- Kawamura, H. and S. Kudo.** 2001. Seabird predation on juvenile chum salmon. NPAFC Tech. Rep. 2:9-10.
- Kawamura, H., S. Kudo, M. Miyamoto, M. Nagata, and K. Hirano.** 2000. Movements, food and predators of juvenile chum salmon (*Oncorhynchus keta*) entering the coastal Sea of Japan off northern Hokkaido in warm and cool years. *N. Pac. Anadr. Fish Comm. Bull.* 2:23-41.
- Kubo, T.** 1946. On the predation on salmonid juveniles by various fishes in rivers. *Sci. Rep. Hokkaido Fish Hatchery* 1:51-55 (in Japanese).
- Nagasawa, K.** 1998. Fish and seabird predation on juvenile chum salmon (*Oncorhynchus keta*) in Japanese coastal waters, and an evaluation of the impact. *N. Pac. Anadr. Fish Comm. Bull.* 1:480-495.
- Nagasawa, K. and M. Kaeriyama.** 1995. Predation by fishes and seabirds on juvenile chum salmon (*Oncorhynchus keta*) in coastal waters of Japan: a review. *Sci. Rep. Hokkaido Salmon Hatchery* 49:41-53 (in Japanese with English abstract).
- Nagata, M.** 1984. Ecological studies on the predation of chum salmon fry by fresh water sculpin, *Cottus nozawae* Synder. *Sci. Rep. Hokkaido Fish Hatchery* 39:55-65 (in Japanese with English abstract).
- Nagata, M. and M. Miyamoto.** 1986. The downstream migration of chum salmon fry, *Oncorhynchus keta*, released into the Utabetsu River of eastern Hidaka in Hokkaido, and the estimation of predation amount of the fry by fresh water sculpin, *Cottus nozawae* Synder. *Sci. Rep. Hokkaido Fish Hatchery* 41:13-22 (in Japanese with English abstract).
- Nakano, S.** 1992. A preliminary report on food habit of Japanese huchen *Hucho perryi* in northern Hokkaido. *Biol. Int. Wat.* 7:20-23 (in Japanese with English abstract).
- Rieman, B. E., R. C. Beamesderfer, S. Vigg, and T. P. Poe.** 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. *Trans. Am. Fish. Soc.* 120:448-458.
- Ruggerone, G. T.** 1986. Consumption of migrating juvenile salmonids by gulls foraging below a Columbia River dam. *Trans. Am. Fish. Soc.* 115:736-742.
- Ruggerone, G. T. and D. E. Rogers.** 1992. Predation on sockeye salmon fry by juvenile coho salmon in the Chignik Lakes, Alaska: implications for salmon management. *North Am. J. Fish. Management* 12:87-102.
- Sakurai, A.** 1984. Chum salmon. Heibonsha, Tokyo, 51 p. (in Japanese).
- Spaans, A. L.** 1971. On the feeding ecology of the herring gull *Larus argentatus* in the northern part of the Netherlands. *Ardea* 59:73-188.

- Tago, Y.** 1994. Feeding habit of juvenile masu salmon, *Oncorhynchus masou*, during the period of seaward migration in the Shou River of Toyama Prefecture. *Bull. Toyama Pref. Fish. Exp. Stn.* 5:13-20 (in Japanese with English abstract).
- Takahashi, A., M. Kuroki, Y. Niizuma, A. Kato, S. Saito, and Y. Watanuki.** 2001. Importance of the Japanese anchovy (*Engraulis japonicus*) to breeding rhinoceros auklets (*Cerorhinca monocerata*) on Teuri Island, Sea of Japan. *Mar. Ecol.* 139:361-371.
- Takami, T. and K. Nagasawa.** 1996. Predation on chum salmon (*Oncorhynchus keta*) fry and masu salmon (*O. masou*) juveniles by white-spotted charr (*Salvelinus leucomaenis*) in a river in northern Japan. *Sci. Rep. Hokkaido Fish Hatchery* 50:45-47.
- Watanuki, Y., M. Aotsuka, and T. Terasawa.** 1986. Status of seabirds breeding on Teuri Island. *Tori* 34:146-150 (in Japanese with English abstract).
- Watanuki, Y., N. Kondo, and H. Nakagawa.** 1988. Status of seabirds breeding in Hokkaido. *Jap. J. Ornithol.* 37:17-32 (in Japanese with English abstract).
- Wood, C. C.** 1987. Predation of juvenile Pacific salmon by the common merganser (*Mergus merganser*) on eastern Vancouver Island. I: Predation during the seaward migration. *Can. J. Fish. Aquat. Sci.* 44:941-949.